Introduction

Using GLOBE Data for Student Research or Inquiry

GLOBE data provide opportunities for student research or inquiry. Because these data come from measurements students have taken themselves, they understand them and are ready to use them in research projects. Since GLOBE measurements are taken following protocols and using instruments which provide results that are useful for professional scientific research, they also support student research. Using GLOBE data, students can experience the full intellectual process that is science, from curiosity through investigation to conclusion and communication.

Through the GLOBE Web site, student data are made readily available. Visualizations allow students to explore data through maps and graphs. Tables of values are available ready for printing or cutting and pasting into spreadsheets and other user programs. The data are also provided in forms which are easy to ingest into geographic information systems (GIS).

The GLOBE Web site also contains reference data from numerous fields of environmental research with worldwide coverage. These data are presented in ways that make comparisons with student data easier. The common user interface for both student and reference data also makes things easier for students.

For GLOBE schools without adequate Web access, selected student data, reference data and visualizations can be provided in hard copy or on computer media on request.

GLOBE student research or inquiry can be done at the local level. Students can make significant contributions to understanding their own part of the world and presenting their community to the rest of the world. Research with GLOBE data can also provide a greater understanding of the larger Earth system.

In addition, students' projects involve areas of study other than science. First, doing student research or inquiry almost always requires use of math skills whether it be calculating averages or identifying and analyzing patterns. Geography skills are also used in investigating spatial patterns of the data. The results of student projects must be communicated to complete the research process. This requires use of spoken and written language skills. Technology, particularly the use of such computer based tools as spreadsheets, word processing, and geographic information systems, is of great advantage in looking at data and communicating results.

In the United States and perhaps some other countries, the term inquiry in the context of science education is in widespread use. While the term inquiry may include a broad spectrum of teaching methodology, it can be agreed that original student research projects are an important component. In much of the world, the term student research is used to mean essentially the same thing. Given the international nature of GLOBE we have employed both terms above and do so in the Gray Box material for protocols and learning activities, but for better flow of the text we use both terms interchangeably.

Support for Student Research or Inquiry in this Teacher's Guide

This edition of the GLOBE Teacher's Guide includes increased materials to support student research. Each protocol now includes a section called *Looking At the Data*. These sections include simple things to look for in determining whether data are reasonable, explanations of some ways in which scientists look at or analyze the data, and an example of a student research project based on use of these data. In some cases, instructions are included for how to calculate important derived information.

In this chapter, Learning Activities are included to provide support for building student abilities to undertake research projects. These activities are

divided into three developmental and technological levels.

Primary activities are designed for young students learning the basics of simple data collection, manipulation of numbers, creating and interpreting graphs, and reasoning with spatial patterns. The activities in this section are *low tech*–they are all done with pencil and paper. Students are guided to learn the basics of using and thinking about data with small data sets and visualizations they develop themselves.

Middle activities are for students ready to move into interpretation of the GLOBE visualizations and to ask their own questions and create their own projects. This section begins with using GLOBE data sets and guides students through the scientific method. The middle activities are *middle tech.* Students use selected GLOBE visualizations and data made available in a *Data Source Book*.

The GLOBE *Data Source Book* is a collection of GLOBE visualizations and data tables selected from around the world. It is available on CD in a format that may be used on a computer or printed as a classroom tool. You may create your own version of a *Data Source Book* from materials on the GLOBE Web site.

A *Data Source Book* provides a number of advantages for teachers and students beginning GLOBE research. First, schools with no or little Internet access can use it to examine GLOBE data and do research projects. Second, students can concentrate on interpretation of the visualizations rather than on the mechanics of computer use, searching for data and creating visualizations. Third, students are directed to a subset of GLOBE data so they are less likely to feel overwhelmed by the millions of data on the Web site and the virtually limitless ways in which they can be viewed. Finally, use of the *Data Source Book* in printed form encourages students to work together looking at the material and talking about their observations whereas using the online form tends to limit groups to two or three students and to minimize discussion. Collaboration is an important skill in research. Students working on computers may often become captivated by interacting with the machine.

Advanced learning activities encourage students to use the full range of the GLOBE data and the Web site to create their own projects. Students are guided in a modeling activity and introduced to more of the features provided, including: resource data sets collected by other programs, output from numerical models, more mapping and statistical features, and the constantly expanding full GLOBE data archive. Advanced activities require students to access the Internet for data and to create their own computer visualization products. Students are also encouraged to use other technically advanced tools such as spreadsheets, statistical or modeling software, and geographic information system software.

Steps to Doing GLOBE Student Inquiry

1. Observe and explore looking at existing data and taking new observations
2. Ask questions and develop a hypothesis
3. Plan the investigation
4. Assemble and organize data
5. Analyze using math skills
6. Conclude using logic to reason your way to conclusions
7. Communicate your results

Step 1. Observe and Explore

How can students find an interesting question to do an investigation?

Scientists often find interesting questions in two ways: they explore and they observe. The GLOBE database is a wonderful place to explore. Students can visit places all over the world. They can explore mountains and valleys, coasts and inland areas, high and low latitudes, cities and farms, rainforests and deserts, and many more. They can also explore close to home, comparing what is happening now to what happened last year.

Observation is another questioning tool of scientists. They make observations about what

they see and compare those observations with what they know or what they see in other places. For instance, you observe that your soil is very red. You live in a desert. Are desert soils always red? Where do you find red soils? What other variables are related to red soil? Another day you notice that sometimes the soil temperature is cooler than the air temperature and sometimes it is not. What things determine how quickly soil heats and cools? Which of these variables is most important?

The GLOBE scientists have provided students with some information on understanding and exploring student data in the *Looking at Data* sections of the protocols in this Guide. You should also read the introductory material provided in this *Teacher's Guide* for each science area. This section provides information on the importance of the measurements being taken. Questions for student thought and discussion are provided along with simple statements for students about why the measurements are important.

Everyone can become an explorer and an observer by spending time using the visualizations provided on the GLOBE Web site. The more time students spend exploring and observing, at the computer or in the environment, the more questions they will ask. Students should keep a log of their explorations and observations as any good scientist, social scientist, writer or artist would. Extra help in setting up and keeping a science log can be found in the *Your GLOBE Science Log* section of this chapter. Students will find that the problem becomes not "what can I do for my project?" but rather "which project shall I do this time!"

Step 2. Ask Questions and Develop a Hypothesis

Probably the most difficult problem students have when asked to do a research project is coming up with an appropriate topic for research. Students tend to ask questions that are so broad they are impossible to address with available data in the time frame given. Typically, students may want to do research on "what are the effects of deforestation" or "what causes our local weather". These topics may make interesting reports where students simply gather literature from a variety of sources about their topic. They do not make good research papers, since students do not generally have the ability to gather or find data addressing these questions and analyze these data themselves.

The middle inquiry learning activities provide guidance on developing questions and hypotheses appropriate for student research. Although these activities are presented in the middle section due to their use of the *mid-tech* GLOBE *Data Source Book*, they may be done equally well using the full GLOBE Web site as an advanced activity.

Step 3. Plan the Investigation

Once students have a topic for research, they should plan their investigation. In this process they should think about the time and effort required and keep the scope and approach for their investigation consistent with the schedule of when things are due and how much effort is appropriate on their part.

You will need to establish specific items that can be handed in to the teacher to help students pace themselves through an investigation. One of the first items might be a project proposal to be reviewed by the teacher or peers before actual work begins.

It may help to have students make a project log of what they do, when they do it, and why they did it. Every time they work on the project, they can take a few minutes to jot down the date, what they did, and what needs to be done next. This may help keep them on task.

Students will also need a means to keep their work together. Creating a project notebook where everything is in one place can meet this need. The log could be part of the notebook, but the notebook should also contain all of the work completed. Students should make tables to record data; print copies of graphs and record on them how they were created; and put in lists of schools, calculations, bibliographic information. The notebook should have everything needed in one place to support the final communication of results.

Plans are useful to organize our thinking about a task and to help us assess what we can accomplish, but once the project is underway, it is natural for things to differ from the details of our initial plans. Students should understand that they do not have to be slavish in following their plans, and students should be assessed on what they accomplish and not on how well they stick to their plans.

The time and effort devoted to planning should be kept in balance with that required for the complete student research or inquiry project. Enough effort should be made so that students have thought through what needs to be done, but generally, much more time should be devoted to observing, exploring, data gathering and manipulation, and documenting results.

You should be prepared to troubleshoot student projects at the planning stage, before most of the time and effort have been expended on the project. Students may need help with such things as recognizing gaps in the data, inappropriate analysis approaches, disconnects between hypotheses and possible results, and unrealistic projects that are too comprehensive for the time allowed or trivial projects that will not require enough work from students. Avoiding student frustration and wasted effort is important. Science involves hard work and can be tedious at times, but the end result should be gratifying to the student.

This process is a part of doing science whether one is a student or a seasoned professional. For the most comprehensive environmental research programs, planning has been known to take years and to involve active discussions involving hundreds of scientists.

Record Keeping

Being organized is a key element in accomplishing whatever you or your students try. As their investigations proceed they may find themselves asking some of the following questions:

When is this part of the project due?

Now, where was that school that had the great example?

How did we calculate the mean of those 40 schools?

Where did I get these data?

To stay organized, students should:

Create a project timeline

Keep track of what tasks have been finished

Maintain a project notebook

Step 4. Assemble and Organize Data

For a research or inquiry project, students need data. These data may be collected by the students themselves or be obtained from the reported measurements of others. The term assemble is used to include both methods of getting data for use in a project.

The GLOBE Protocols provide students with scientifically sound methods to use in collecting data. These protocols give students a measurement vocabulary that can be used to collect data beyond those routinely reported to GLOBE. For instance, the protocols for pH measurement can be used on water from sources that are not natural or on separate snow samples taken from the top, middle, and bottom of a major snow fall. Also, the protocols can serve as examples for students in developing their own protocols for different measurements. Here students may benefit from having their protocols reviewed by a local scientist or through communications with one of the GLOBE scientists.

Regardless of how the students get their data, the data will need to be organized in some systematic way. This organization could consist of arranging the data in a table in the student's science log or involve the use of computer software such as spreadsheets or geographic information systems.

Student organization of data should:

Be complete (no data are omitted)

Indicate the source(s) of the data

Present the data clearly (in a way that makes them easily understood)

Make analysis of the data as easy as possible

Clearly give the units of the data

State the accuracy and precision of the measurements (for students who will be considering questions of accuracy quantitatively)

Associate metadata with the data (to help in correct interpretation).

Step 5. Analyze Using Math

Analysis of data involves mathematics including reasoning with patterns as well as numbers and doing calculations. In general, student research projects associated with GLOBE will involve comparisons of data and quantities derived from these data and not the calculation of a single number such as the monthly average rainfall of a place.

Analysis includes:

- How the way in which the data were obtained may have affected the values obtained
- How the data support or refute the research hypothesis

The type of analysis students do will depend on their level in school. The youngest students can count, or maybe add and subtract. As students learn more math and higher level thinking skills, the level of analysis should increase.

Primary Activity Analysis

Organizing and visualizing data help students to understand the measurements they make. Once they are able to interpret their data, students can begin to answer some of their own questions about their environment.

The first section of the Inquiry Learning Activities, *What Do You Do With a Data Point?*, guides students in manipulating the numbers they have collected to answer simple questions. Students will begin by arranging their data numbers in different ways (supporting Step 4) to answer different questions. They will learn to draw a graph to see data patterns, and to put two lines on a graph to compare different data. Finally, they will be introduced to spatial patterns as a precursor to mapping.

Math skills include:

- Counting
- Adding and subtracting
- Grouping
- Visual comparison of graphs and maps
- Spatial grouping

Middle Activity Analysis

The scientific method, as outlined in this series of activities, is not a series of steps to be memorized, it is a process of thinking and discovery. Students will not 'learn' this process by memorizing the steps. Each of the activities is simply one example of a step in the scientific process. In the GLOBE *Data Source Book* sets of data are provided that can be used to complete each activity. If students are interested in seeing the most current data, or in graphing or mapping the data in a different format, they can use the GLOBE visualizations Web site. It is recommended that students begin with the smaller data sets and expand their projects to larger data sets when they have an understanding of the concepts. The opportunity for research is virtually endless.

Math skills include:

- Normalization of data
  - Percentages
  - Ratios
- Simple statistics
  - Averages: mean, median, and mode
  - Histograms
  - Standard Deviation
- Mapping and regional analysis

Advanced Activity Analysis

Scientists often must do research with less than complete data sets. A lack of adequate time or resources, or adverse environmental conditions may cause data sets to be incomplete. Sometimes conclusions can be made based on inferred data. In this section, students will think about such data strategies as sampling from a large data set, creating a model to fill in missing data, and combining various data sets.

Math skills include:

- Sampling
- Modeling
- Using models and large data sets

Step 6. Conclude

The key conclusion to a research effort is whether the hypothesis has been supported or refuted. Logically, it is much easier to show through example that something is untrue than to show that it is always true. This is one reason why hypotheses are usually refuted and seldom proven in science.

The keys to good conclusions in research projects are that they are firmly anchored in the results of the analysis and that they are reached in a logical, reasoned fashion.

Step 7. Communicate Your Results

Every scientist needs to publish the work they do. Unless a scientist lets others know what he or she has discovered, the work is lost. Progress is only made when we share what we have discovered.

It is important to realize that when scientists help to understand a new small part of the world, they must show others how their part fits into a larger whole. This means that they must acknowledge the intellectual contributions of others. When you publish your work, in whatever format, you must include references to sources of data, ideas about or help with analysis, and related contributions published elsewhere. This includes data and information found on the Internet. Even though much of the content found on the Web appears to be "free," anything useful in research always has an intellectual source that must be acknowledged. Such acknowledgments do not weaken your own work, but actually strengthen it by giving others confidence that your work is your own, and that you understand and have made fair use of the work of others when reaching your own conclusions.

GLOBE offers opportunities on the GLOBE Web site for students to publish their results. In addition, there are occasional opportunities to present student work at GLOBE conferences and learning expeditions. Also, you may find local interest in your results and opportunities to present your research. Many GLOBE schools have presented their research to city councils, school boards, and other community groups. It may be that your understanding of the local environment as a GLOBE student is unique. Share your knowledge with others in your community.

Content

Use the following checklist to ensure that all elements of the research project are presented.

- Title
- Student(s) name(s) and the name(s) of any other contributors
- The hypothesis
- Data
- Identification of data sources or measurement techniques
- Method: sampling, classification system, replication, analysis (what calculations were done to which data and what were the results)
- Explanation of how the results were interpreted and the conclusions reached
- Discussion putting the investigation in context which could include a comparison of this work to similar studies including appropriate attributions*
- Statement of whether the hypothesis was refuted or supported and why
- Description of limitations of the research*
- Discussion of further research possibilities
- References

* These elements may be presented at any place in a report.

Clarity

Items to check for clarity of presentation:

- Are the hypothesis, and conclusions clearly stated?
- Are formulas for calculations given?
- Are graphs, maps, tables, and illustrations clearly labeled?
- Are graphs, maps, and illustrations simple enough to be understood easily?
- Are units given for every parameter in text, labels, and formulas?
- Will the vocabulary used be understood by the audience?
- Are any special terms clearly defined?

Publication on the GLOBE Web site

For professional research papers, reviewers and editors are expected to insist that standards are met. In GLOBE student research presentations, teachers serve as reviewers and editors. For publication on the GLOBE Web site, teachers are asked to check work using the above lists for content and clarity. In addition, to approximate the scientific process, student communications should:

- Not omit anything which might call into question the conclusions
- Give clear credit to all contributions by others, including references to materials obtained from outside sources (e.g., books, the Web)
- Demonstrate that the students understand their work, especially the analyses and the reasoning that led to their conclusions.